The MODIS-VIIRS Cloud Mask (MVCM) with Comparisons to CALIOP

Richard A. Frey[a], Steven A. Ackerman[a,b], Alexa Ross[a], and Robert Holz[a]

[a]Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin-Madison

[b]Department of Atmospheric and Oceanic Sciences

MODIS-VIIRS Cloud Mask (MVCM)

MVCM "philosophy" same as for MODIS cloud mask (MOD35)

Uses consistent spectral bands from both MODIS and VIIRS

For historical reasons, 3.95-11.1 µm is used for MODIS BTD cloud tests while 3.75-11.1 µm is used for VIIRS. The VIIRS 4.05 µm band is not a viable substitute for the MODIS 3.95 µm band.

MVCM contains similar output as MOD35 (48 bits/pixel)

MVCM output contains confidence of clear sky (Q) values

MVCM output contains integer cloud mask array (values of 0-3)

Ancillary data similar to MODIS (GDAS, SSTs, LST, etc.)

Output file is in netcdf format

Some improvements made over MODIS Collection 6 MOD35:

Solar and viewing zenith angle corrections to 0.86 and 1.38 µm ocean cloud test thresholds

Viewing zenith angle corrections to 0.65 µm land cloud test thresholds

Surface snow detection improvements in taiga and montane environments

Improvements Since June 2016 STM

Output netcdf file

Added integer cloud mask array (equivalent of cloud mask bits 1 and 2)

Threshold adjustments to 11-4 µm ocean stratus test

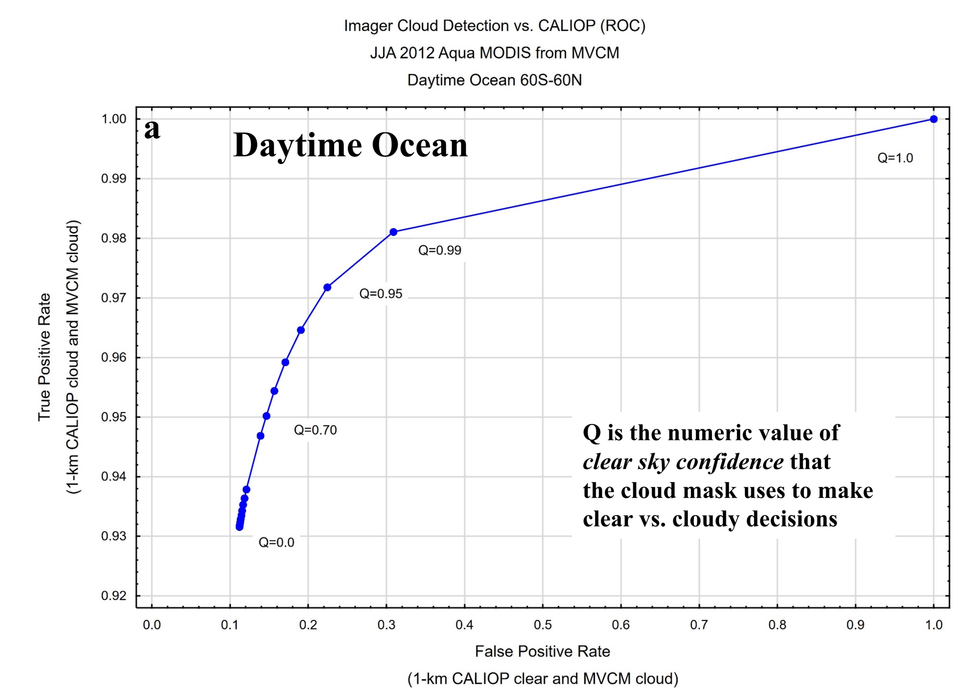
Threshold adjustments to 8.6-11 µm test

Threshold adjustments to 8.6-7.3 µm test

To reduce overclouding:

Threshold adjustments to Aqua 3.9-11 day ocean test

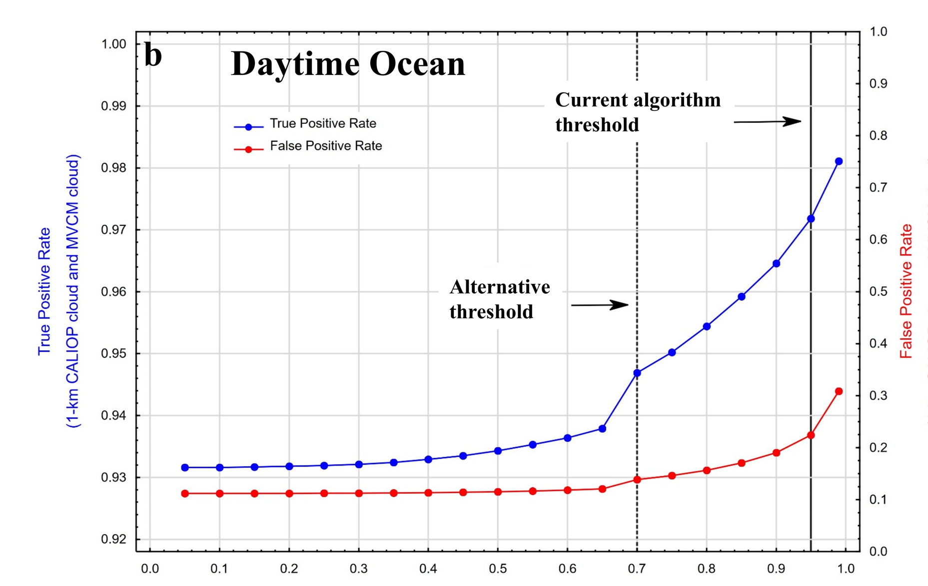
Threshold adjustments to Aqua/VIIRS 2.1/1.6 day ocean test

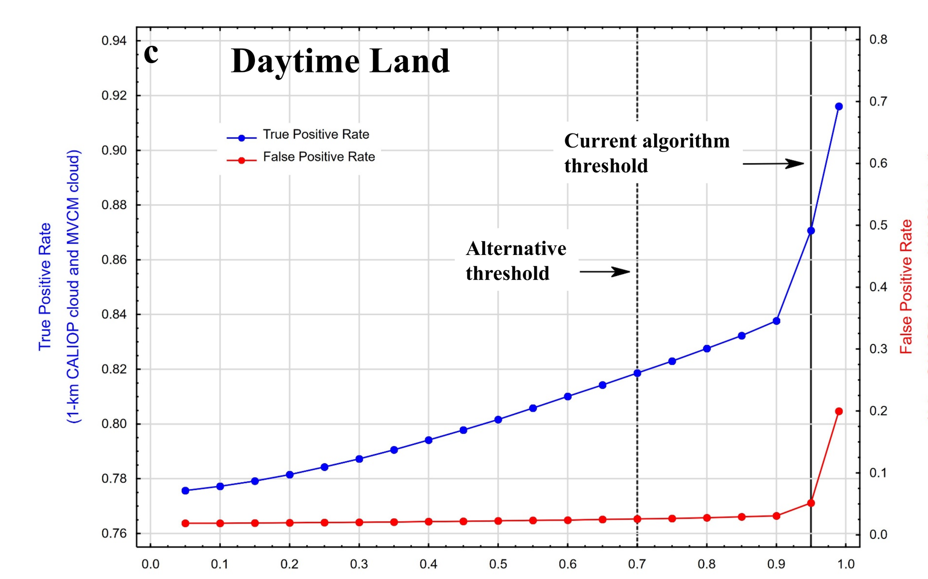


MVCM vs. CALIOP Diagnostics

Plot at top right (a) shows cloud detection rate (true positive) vs. false cloud rate (x-axis). Receiver Operating Characteristic (ROC) curves such as this one may be used to determine the ability of a binary classifier (clear vs. cloud) as a discrimination threshold is varied (in this case, the clear sky confidence, or Q). Second plot at right (b) shows the same information but where the plot components are rearranged. The second plot clearly shows that one could lower the Q-threshold to about 0.70 (dashed vertical line) from the current value (solid vertical line) which would decrease cloud detection by about 2.5% but also decrease false alarms by about 8%. We are investigating pros and cons of such changes on a global and regional basis.

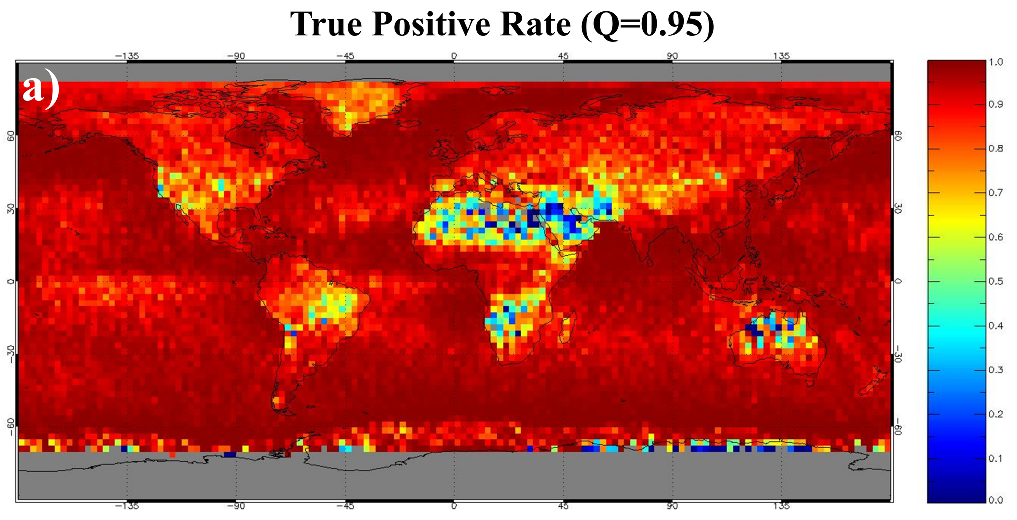
Using the same arguments on the third plot to the right (c), we see that not as much is gained by moving the Q threshold to 0.7. We would decrease the cloud detection rate by about 5% but decrease the number of false alarms by only about 2.5%. Clearly in this case, we would continue to use the current algorithm threshold of 0.95.



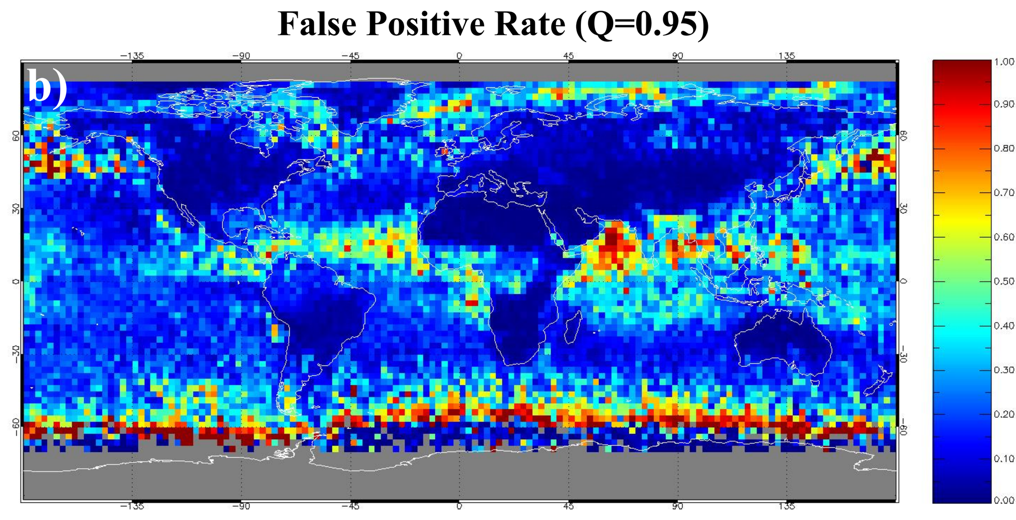


The maps below show parameters related to ROC analyses for 2.5-degree regions. Maps a-f are: a) daytime MVCM Aqua cloud detection hit rates (true positive rates), b) same as a but for false alarm rates (false positive rates), c) same as a but for Q=0.70, d) same as b but for Q=0.70. Map e shows combined cloudy and clear sky hit rates when Q=0.95, and f is the same as e but for Q=0.70.

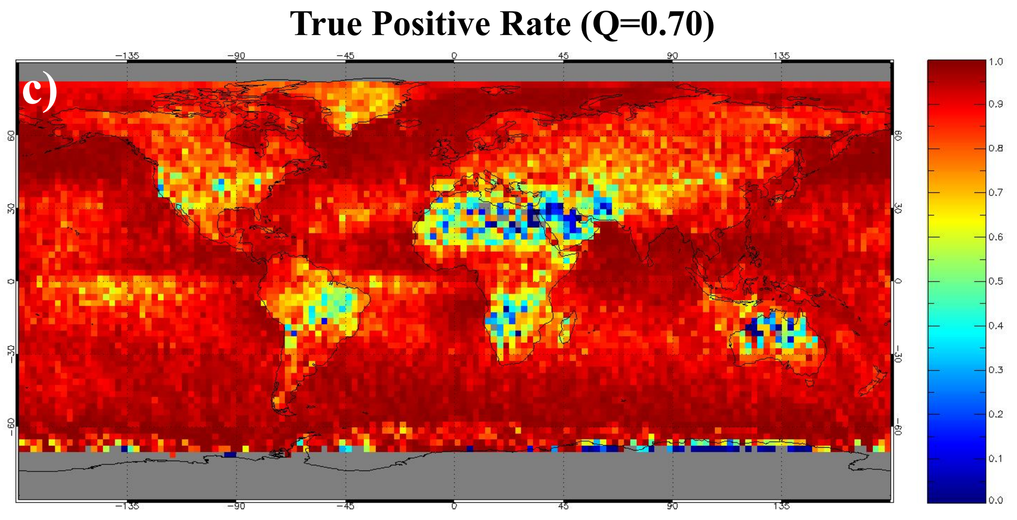
True Positive Rate (Q=0.95)



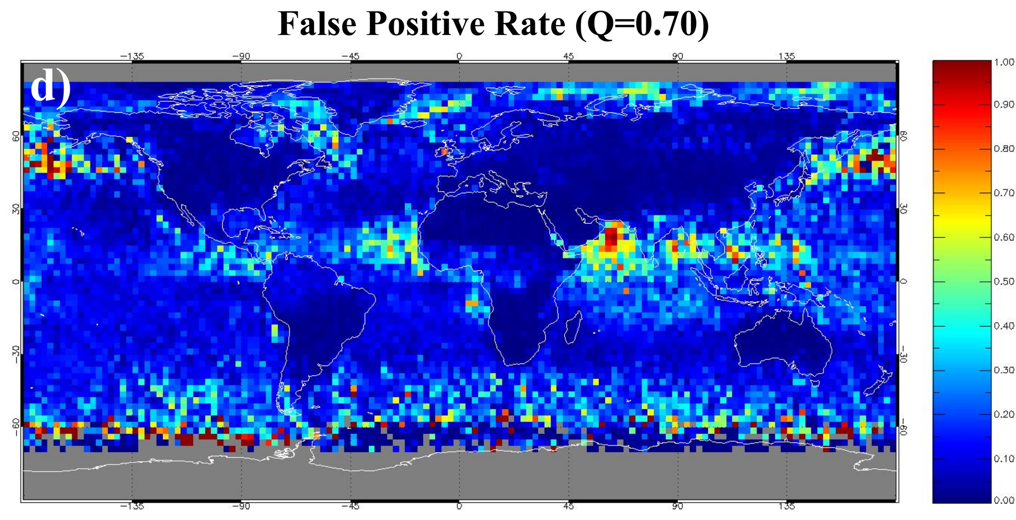
False Positive Rate (Q=0.95)



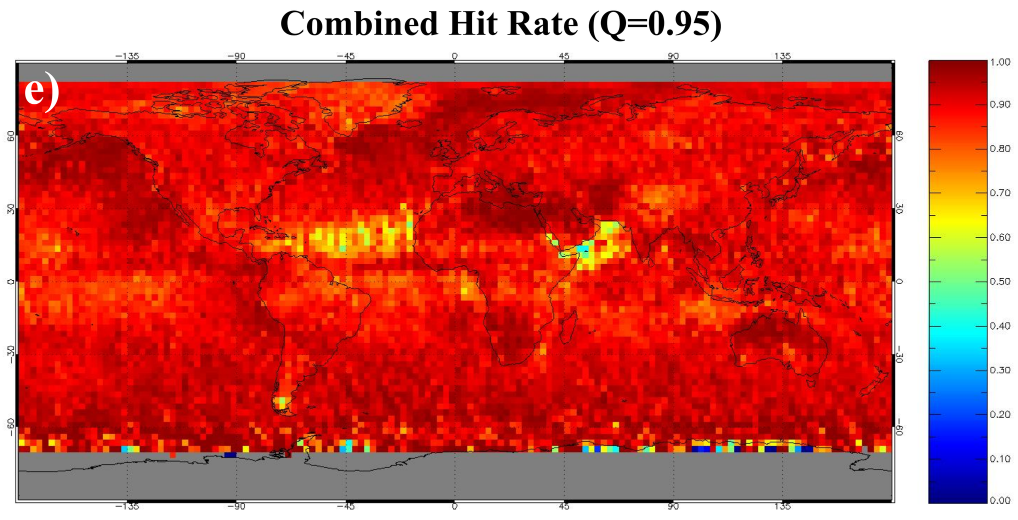
True Positive Rate (Q=0.70)



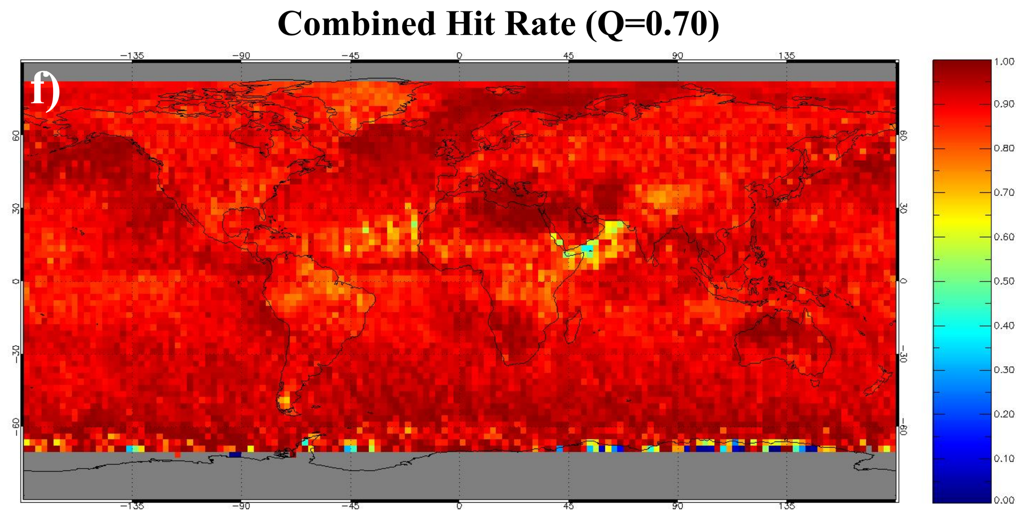
False Positive Rate (Q=0.70)



Combined Hit Rate (Q=0.95)

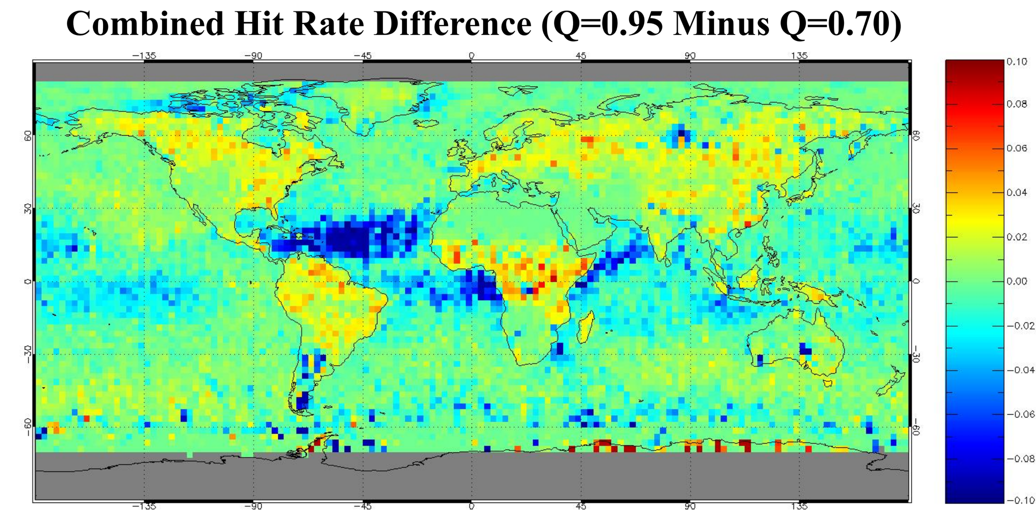


Combined Hit Rate (Q=0.70)



The map directly below shows the difference in combined hit rates (cloudy and clear sky combined) between Q=0.95 and Q=0.70. Positive increases in hit rates (improvement) are indicated by negative values while decreases in performance are indicated by positive differences. Note that ***land areas have not benefitted*** from the change from Q=0.95 to Q=0.70 (see above), so we would let land surfaces alone. ***Tropical ocean areas do benefit with regions characterized by aerosols improving the most***. Some mid-latitude oceans see a modest decrease in hit rates.

Combined Hit Rate Difference (Q=0.95 Minus Q=0.70)



MYD35, MVCM Aqua MODIS, MVCM SNPP VIIRS Hit Rates vs. CALIOP

MYD35, MVCM MODIS, and MVCM VIIRS vs. CALIOP Cloud Detection						
Scene Type	JJA 2012 Hit Rates (%)			DJF 2012-13 Hit Rates (%)		
	MYD35	Aqua MODIS	VIIRS	MYD35	Aqua MODIS	VIIRS
Global	88.4	87.8	86.9	88.2	86.6	86.7
60N-60S	91.0	90.9	90.2	90.4	89.9	89.7
Global Day	91.4	90.8	89.1	90.7	90.1	89.2
Global Night	85.8	85.1	85.0	85.9	83.6	84.6
60S-60N Day	91.5	91.0	89.9	91.2	90.6	90.3
60S-60N Night	90.6	90.8	90.6	89.7	89.2	89.0
60S-60N Water Day	91.8	91.1	90.1	92.7	91.4	91.4
60S-60N Water Nt	90.3	90.3	90.0	90.8	90.7	90.3
60S-60N Land Day	90.6	90.9	88.9	87.1	88.1	86.7
60S-60N Land Nt	91.5	92.1	92.1	86.5	85.2	85.9
60S-60N Desert Day	91.5	91.7	90.4	86.5	87.3	84.8
60S-60N Desert Nt	91.0	91.4	91.3	83.9	83.9	86.5
Polar Day	91.1	90.2	87.2	89.6	89.0	86.4
Polar Night	76.9	73.7	74.1	79.5	73.8	77.0

Table at left shows overall hit rates (cloud agreement plus clear sky agreement) when MYD35 v6.1, MVCM Aqua MODIS, and MVCM SNPP VIIRS are compared to CALIOP lidar (truth). Time coverage is June-August, 2012 (LHS) and December 2012-February 2013 (RHS).

Globally, MVCM MODIS < MYD35 by 0.6% in JJA and 1.6% in DJF, where the latter difference comes primarily from polar night conditions. Agreement discrepancies are smaller for 60S-60N overall. In other 60S-60N categories, MYD35 vs. MVCM MODIS differences are generally < 1% and MVCM even exceeds MYD35 in some scene types.

Globally, MVCM VIIRS < MVCM MODIS during JJA but slightly higher during DJF. Generally, MVCM VIIRS < MVCM MODIS in both seasons except Arctic polar night and land night. It is not clear what causes lower agreements to CALIOP for MVCM VIIRS. Larger view angle differences, calibration differences, smaller numbers of collocations, as well as suboptimal cloud test thresholds are all suspects.

Comments

1) **Version 1.0 of the MODIS-VIIRS (Continuity) Cloud Mask (MVCM) is ready for production.**

2) **The output of the MVCM will include confidence of clear sky (Q), the value used to determine confident clear, probably clear, probably cloudy, and cloudy categories. We are investigating ways in which users may employ these values to maximize cloud mask utility.**

3) **MVCM Aqua MODIS, MVCM SNPP VIIRS, and Aqua MYD35 agree well with each other in a 3-way comparison to CALIOP lidar cloud detection data. Globally and overall from 60S-60N, MYD35 agrees best with CALIOP because more bands (information) are utilized. However, MVCM Aqua shows higher agreement than MYD35 for daytime land and NH summer nighttime land. MVCM VIIRS shows overall slightly lower agreement with CALIOP than MVCM MODIS, excepting Arctic polar night and nighttime land. The reason(s) for this are unclear but work continues to maximize continuity between MODIS and VIIRS cloud detection.**